Bioethanol Production in Pulp and Paper Industry

Introduction

After two centuries of almost absolute belief in technical and economic progress, human society is in a period of reconsideration and elaboration of new strategies for the ongoing new century. The progress made by our civilization, with an explosive rise in world population has led to an enormous consumption increase of resources and to an equal threat to the environment. In this context, biotechnology is considered to play a significant role. Notably the question of responsible use of resources for food, energy, and alternative products and production processes has created various reasonable solutions following the crisis in the early 1970s - new routes, but also rediscoveries of others which have been developed under different conditions in the past. In the future, our energy systems will need to be renewable and sustainable, efficient and cost-effective, convenient and safe (Chum and Overend, 2001).

One of the examples discussed as possible alternative that has been investigated during the last few decades is the production of ethanol from various feedstock (Roehr, 2001). One important feedstock is represented by lignocellulosic materials. Lignocellulosic biomass in nature is by far the most abundant raw material from hardwood, softwood, grasses and agricultural residues (Lee, 1997).Ethanol produced from lignocellulosic materials has the potential to be a valuable substitute for, or complement to, gasoline (Piccolo and Bezzo, 2007). Along with this acceptance has come increased interest in commercializing technology for production of ethanol from potentially inexpensive cellulosic feedstocks (Schell *et al.*, 2004). A wide variety of processes for the production of ethanol from cellulosic materials have been studied and are currently under development (Piccolo and Bezzo, 2007). The main components of cellulosic biomass as well as their hydroylysis products are presented in Figure 1.

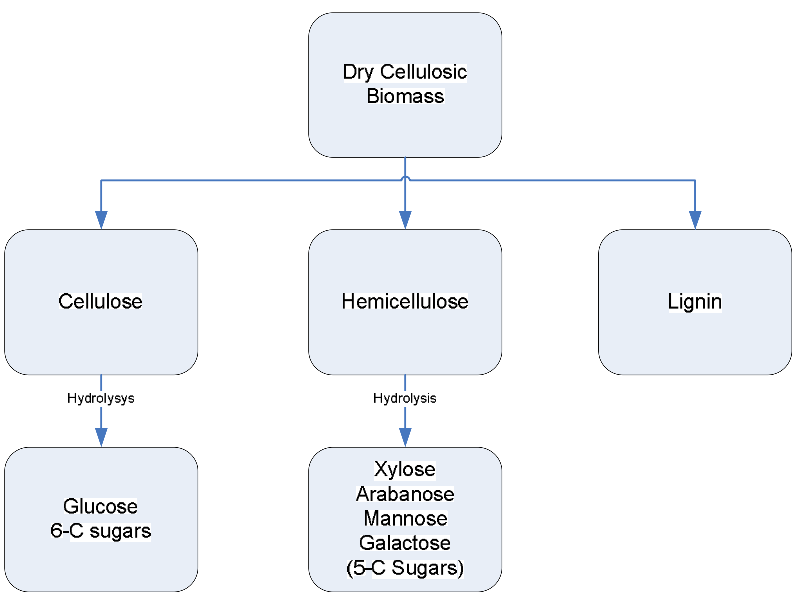

Figure 1. Cellulosic components and their correspondent hydrolysis components

Bioethanol production in pulp and paper industry is presented below. The steps of the process are schematicaly presented in Figure 2.

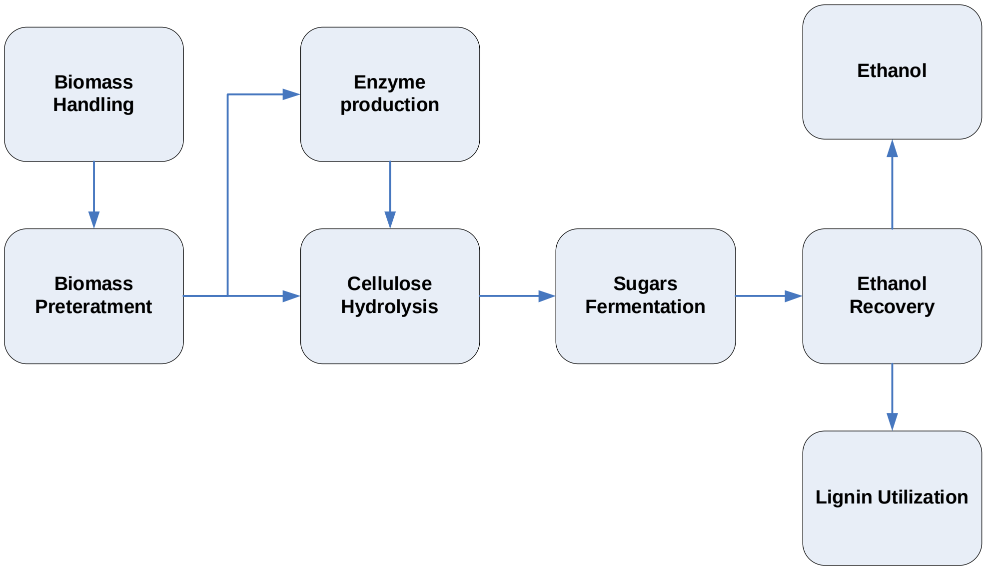

Figure 2. Main steps of bioethanol production

The process described below is focused on the two main sections:

1. Reaction section: Sugars (glucose, mannose) conversion to ethanol
2. Separation Section: Ethanol separation

Fermentation is the biochemical process that converts sugars into ethanol (alcohol). The most important reactions which occur are:

$$\underset{glucose}{C_6H_{12}O_6} \rightarrow 2\underset{ethanol}{C_2H_5OH} + 2CO_2$$

$$\underset{mannose}{C_6H_{12}O_6} \rightarrow 2\underset{ethanol}{C_2H_5OH} + 2CO_2$$

The assumptions made here are that glucose and mannose are completely converted. The conversion values are reported in Table 1.

Table 1. Conversion data for ethanol production process

REACTION NAME	REFERENCE COMPOUND	CONVERSION (%)
R 1	Glucose	100
R 2	Mannose	100

The simplified schema of the process is presented in Figure 3.

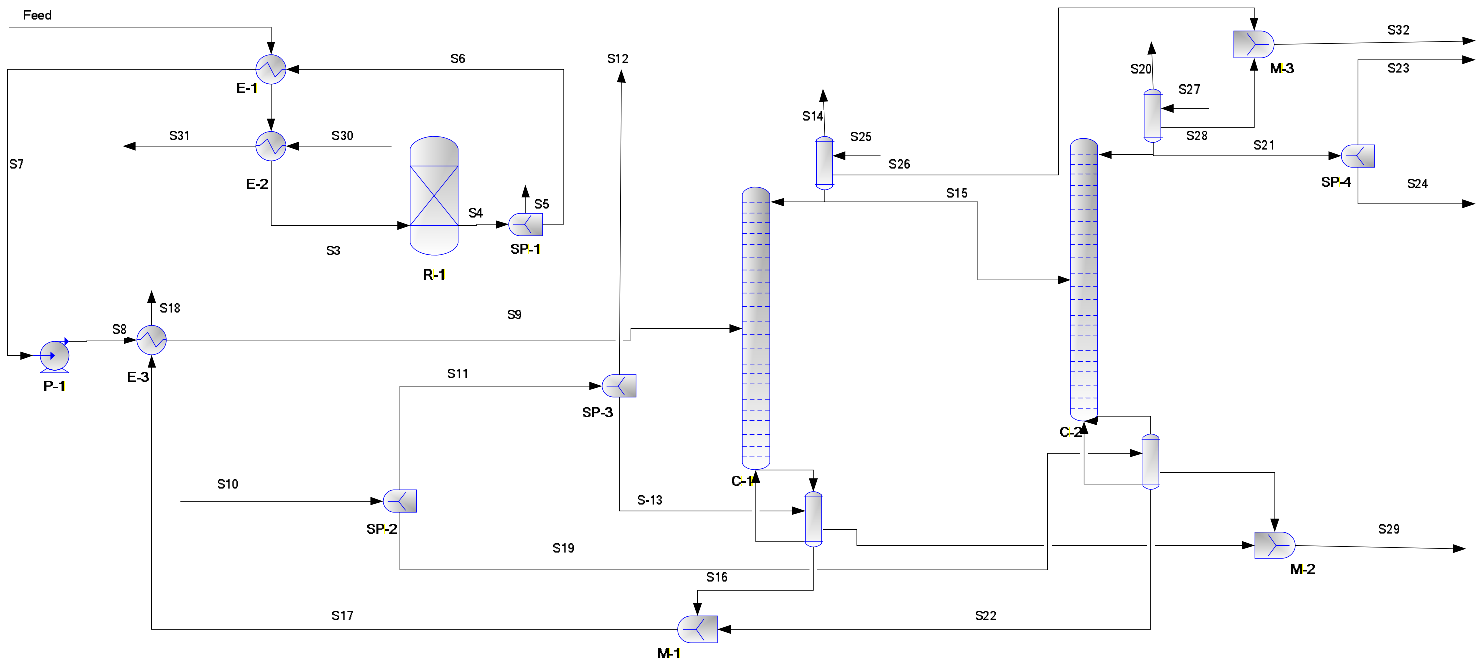

Figure 3. Ethanol production process

Process Description

The raw material, Feed, is cooled in two heat exchangers (E-1 and E-2) and the resulting stream, S3, is sent directly to the fermentor, R-1. The reactions described in the previous part occur in the reactor. The resulting stream S4 is splitted. S5 containing CO_2 is released into the atmosphere while the liquid stream, S6, is sent to a pump and to another heat exchanger, E-3, in order to modify the pressure and the temperature of the input stream (S9) to the first distillation column C-1. Ethanol is concentrated up to 50% in this column. After first distillation the ethanol solution contains, approximately, 50% of water and 50% of ethanol. In order to obtain a solution with 95% of ethanol, a second distillation is necessary. The distillate of the first column, S15, is sent to the second column (C-2) in order to obtain concentrated ethanol. The distillate of the second column, S21, is splitted again in order to obtain pure ethanol in S23. The quantity of ethanol obtained in the plant is 11596.5 lbs/hr. The bottom streams of both columns (S16 and S22) are mixed in M-1 and used to heat S8. Stream S10 contains the steam requested to heat the reboilers of both distillation column. The outlet streams of the reboilers as well as the outlet streams of the condensers are mixed in M-2, respectively M-3, and are used in another part of the pulp and paper mill.

Process Simulation

The process has been simulated using apiMAX process simulator.

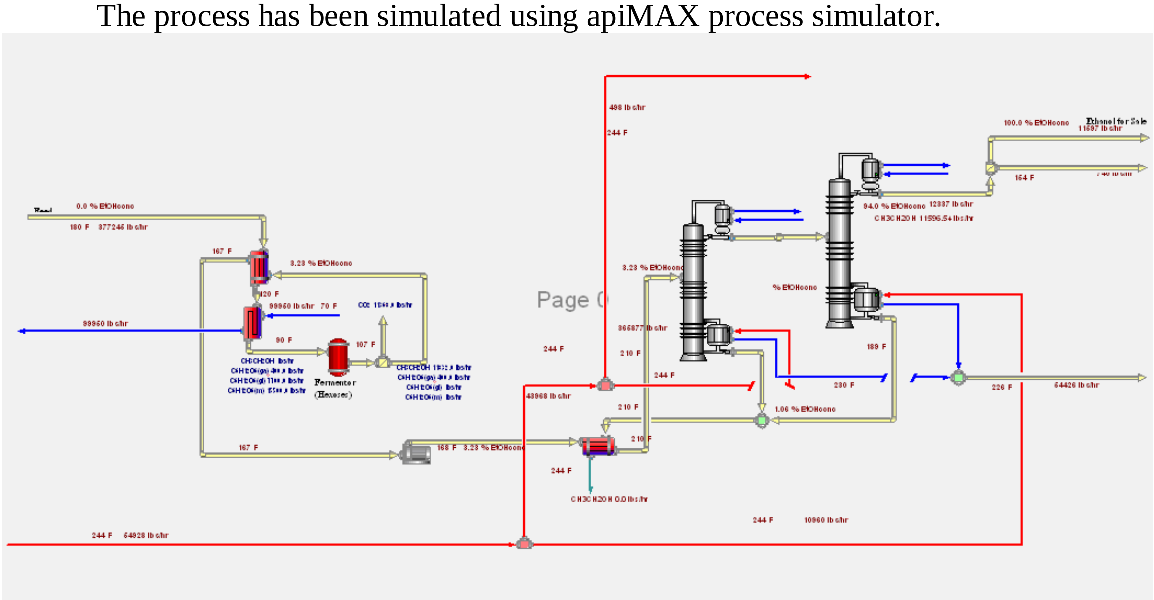

Figure 2. apiMAX schema of ethanol production process

The thermodynamic methods used in the present simulation are: UNIFAC for activity coefficients, Antoine for saturation pressure calculation, SRK for equation of state model, gamma-phi approach for K-values and pulping correlations for boiling point rise method.

The input process streams are reported in Table 2 and the output process streams are summarized in Table 3.

Table 2. Input streams results ethanol production process

STREAM NAME		**Feed**	**S30**	**S10**	**S25**	**S27**
STREAM DESCRIPTION						
TEMPERATURE	F	180	70	244	70	70
PRESSURE	PSIG	0	0	10	0	0
TOTAL MASS RATE	LB/HR	377245	99950	54927.6	377698	138234
TOTAL WEIGHT COMP. RATES	LB/HR					
H_20		318500	99950	54927.6	377698	138234
OH^-		14110	0	0	0	0
H^+		145	0	0	0	0
CH_3OH		1465	0	0	0	0
Ca^{2+}		7700	0	0	0	0
$C_{10}H_{16}$		1425	0	0	0	0
$C_5H_{10}O_5$(x)		6875	0	0	0	0
$C_6H_{12}O_6$ (ga)		400	0	0	0	0
$C_6H_{12}O_6$ (gl)		7700	0	0	0	0
$C_6H_{12}O_6$ (m)		15500	0	0	0	0
$C_6H_{12}O_7$		850	0	0	0	0
$C_5H_{10}O_5$ (a)		975	0	0	0	0
HHc		1500	0	0	0	0
CH_3CO_2H		100	0	0	0	0

Table 3. Output streams specifications for ethanol production process

STREAM NAME		S5	S31	S18	S26	S28	S23	S24	S29
STREAM DESCRIPTION									
TEMPERATURE	F	106.906	173.672	174.527	175	150	153.86	153.86	225.979
PRESSURE	PSIG	0	0	0	0	0	-5	-5	10
TOTAL MASS RATE	LB/HR	13323.9	99950	351840	377698	138234	11596.5	740.205	54426.4
TOTAL WIEGHT COMP.RATES	LB/HR								
CO_2		13323.9	0	0	0	0	0	0	0
H_2O		0	99950	317760	377698	138234	0	740.205	54426.4
H^+		0	0	145	0	0	0	0	0
OH^-		0	0	14110	0	0	0	0	0
$C_{10}H_{16}$		0	0	1425	0	0	0	0	0
$C_5H_{10}O_5$ (x)		0	0	6875	0	0	0	0	0
$C_6H_{12}O_6$ (ga)		0	0	400	0	0	0	0	0
$C_6H_{12}O_7$		0	0	850	0	0	0	0	0
$C_5H_{10}O_5$ (a)		0	0	0	0	0	0	0	0
HHc		0	0	1500	0	0	0	0	0
Ca^{2+}		0	0	7700	0	0	0	0	0
CH_3CO_2H		0	0	100	0	0	0	0	0
CH_3CH_2OH		0	0	0	0	0	11596.5	0	0

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